**Science Benchmark: 06 :02**
Earth turns on an axis that is tilted relative to the plane of Earth's yearly orbit. The tilt causes sunlight to fall more intensely on different parts of the Earth during various parts of the year. The differences in heating of Earth's surface and length of daylight hours produce the seasons.

**Standard 02:**
Students will understand how Earth's tilt on its axis changes the length of daylight and creates the season.
**Objective 1:**
Describe the relationship between the tilt of Earth's axis and its yearly orbit around the sun.

**<u>Activity 1:</u> Reasons for the Seasons**

**<u>Intended Learning Outcomes:</u>**
1-Use science process and thinking skills
2-Manifest scientific attitudes and interests
3-Understand science concepts and principles
4-Communicate effectively using science language and reasoning
5-Demonstrate awareness of social and historical aspects of science
6-Understand the nature of science

**<u>Teacher Background:</u>**
Have you ever run laps on a track? When you complete one lap you are back in the same place you started. Earth moves around the sun in a path that nearly repeats itself (like running a track) about every 365.25 days. Earth's path around the sun is called its orbit.

Earth's axis of rotation is an imaginary line that passes through Earth's North and South poles. Earth rotates around this axis, which causes day and night. Earth's axis of rotation is not straight up and down with respect to its orbit, but is tilted by about 23.5 degrees with respect to this up and down direction.

If you have ever watched the North Star, you may have noticed that it seems to stay in the same place in the sky all of the time. It is almost directly above Earth's North pole. This shows that Earth's axis of rotation points in the same direction while Earth both rotates on its axis *and* moves in its orbit around the sun. About June 21 every year, Earth is at a place in its orbit where the northern side of its axis is tilted toward the sun. Six months later, about December 21, Earth is on the other side of the sun where its northern axis is tilted away from the sun.

When the northern side of Earth is pointed away from the sun in December, the sun appears low in the sky and the angle of the sun's rays is small. In June when the northern side of Earth is pointed toward the sun, the sun appears high in the sky, and the angle of the sun's rays is large. In the spring and fall the angle of the sun's rays is half way between the angle in winter and the angle in summer.

The days with the least amount of daylight are not the coldest days, nor are the days with the most amount of daylight the warmest days. This is because some materials can be heated and cooled quickly (especially metals). Other materials can absorb heat without changing their temperature very much, so it takes a long time to heat and cool them. Water is a good example of this. About 3/4 of Earth's surface is covered by water which causes the heating and cooling of Earth to take place slowly. Although the maximum amount of heat received by the sun in the Northern hemisphere occurs on June 21, the highest average temperatures occur about one month later. Similarly, the lowest average temperatures occur *after* the date when the Northern Hemisphere receives the least amount from the sun.

**Materials:**

- " Season Survey", 2-3 copies per student
- meter sticks or measuring tapes
- lamp or flashlight
- dark room
- outdoor thermometer (a minimum/maximum thermometer would be ideal)
- graphing paper
- sunrise/sunset and temperature dates for Salt Lake City

**Invitation to Learn:**

Give each student 2 or more copies of the "Season Survey." Have each student complete a copy of the survey. Have them ask a family member or friend (not a member of the class) to complete the other(s). When all the surveys have been completed, together as a class, tally the number of responses for each answer choice for each survey question. Discuss with the class to determine which answers are correct. If a particular answer had the highest number of responses, does that mean that it is the correct answer? Explain that historically the majority of people have believed incorrect ideas. Ask if they can think of any examples? (Earth is flat; Earth is center of the universe) Explain that the best way to find out the correct answers is to research the problem. This will be done by making observations and by learning what other scientists have discovered.

**Instructional Procedures:**

In this activity students will learn how Earth's axis of rotation affects the angle of sunlight and the length of day. Students will first learn the relationship between the height of a light source and the length of the shadow cast by an object in the path of the light source. Next they will record shadow lengths to infer changes in the sun's angle over at least a 3-month period. They will also record the high temperatures on the days where shadow lengths are recorded. Finally, students will compare day length with the high temperatures.

1. In a darkened room have a student hold a meter stick upright where everyone will be able to see the shadow. Move the lamp or flashlight up and down to show that when the light source is high, the shadow cast by the meter stick is short. When the light source is low, the shadow is long. Have another student sit near the meter stick and have them point to the light source with their extended arm. The angle of the student's arm is large when the light source is high and smaller when the light source is low.

Sun Shadow Observations
WARNING!
Never look directly at the sun!

2. Begin shadow measurements on a sunny day. Select a straight up and down object on the school grounds such as a flagpole, tetherball pole, or basketball standard. Choose a time of day when students will be able to consistently make measurements (perhaps a recess break). **It is very important that the shadow be measured at the same time of day each time it is measured.** With the whole class watching, demonstrate how to measure the shadow cast by the object. It is also important that it is measured consistently each time.

3. Before going outside to measure, decide on a format for keeping track of the records in student science journals. Have students record the date, time and length of the shadow in their science journals.

4. Arrange for an outdoor thermometer to be placed outside your classroom (not in direct sunlight). Have students record the high temperature for the days they observe the sun's shadow. You will need to work out a system for finding the high reading. Thermometers are available with a remote sensor so they could be read inside. Or, if you use a minimum/maximum thermometer it will automatically register the high (and low) temperature each day. An alternative to tracking and recording the actual temperatures is to find and record the official weather temperatures in the newspaper or on the Internet. See "Resources" for Internet sites.

5. Continue to make observations with the whole class for about a week. Little change will be noticed, but it will set the pattern for further observations.

6. Organize the class in teams of two or three to continue making observations. Arrange a schedule for the class observations and a method for sharing information with other class members. Continue to make records for a period of at least 3 months. Ideally it would be best to keep records through the school year so students could see the seasonal changes.

7. Periodically discuss with your class what is happening to the length of the shadow. Have them note what is happening to the amount of daylight. This is a good time to discuss sunrise and sunset times. Discuss why this is happening. Be sure students know that Earth's axis of rotation is the reason for the sun's changing position in the sky.

8. Have students calculate the length of daylight for two days each month. Or you may have students gather information from newspaper or Internet sources or from class observations.

9. After sufficient data is collected, organize students in small groups to make the following series of graphs: a graph showing the shadow changes, a graph showing temperature highs, and a graph showing length of daylight. Compare the similarities and differences of the three graphs. Students may notice that the coldest days are not the days with the shortest shadow or the least amount of daylight. Help them understand that one reason for this discrepancy is because the materials Earth is made of take time to cool and warm.

**Possible Extensions/Adaptations/Integration:**

1. Students locate and use Internet sources to keep track of sunrises and sunsets and daily temperatures.
2. Have students make two or three graphs on the same graph paper to show comparisons.
3. Use this demonstration to show students how water heats and cools relatively slowly. Fill a pan with water and place it on a hot plate, turned on high. Help students notice that the pan heats up quickly, but the water does not. Monitor the temperature of the water through out the experiment. Turn the hot plate down slightly to medium-high. Observe whether the water becomes immediately cooler. It does not. Actually the water temperature may go up. The water temperature does not respond quickly to temperature changes. Relate this to how the earth's surface (3/4 water) does not heat up or cool down immediately.

**Assessment Suggestions:**

1. Refer to the original survey students took at the beginning of the unit. Have them take the survey again. Discuss the correct answers.
2. Have students choose one misconception about the way people erroneously think about the seasons and write why the misconception is false and what the correct answer is.

**Additional Resources:**

http://www.wrh.noaa.gov/Saltlake/climate/temperature.html

This website is an interactive map and will list the high and low temperatures for many cities in Utah during the preceding 5 days.

http://www.wrh.noaa.gov/Saltlake/climate/temperature.txt.html#UT002

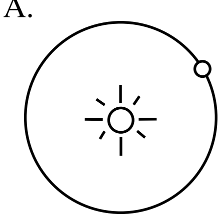
This website is the text version of the above site.

Gould, Alan, Carolyn Willard and Stephen Pompea. *The Real Reasons for Seasons Sun- Earth Connections*. GEMS Lawrence Hall of Science, University of Berkeley, CA, 2002.

# Season Survey

**Which drawing do you think most accurately shows the shape of the Earth's orbit around the sun?**

A.



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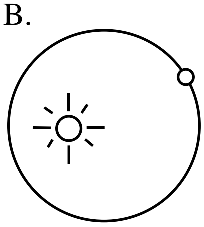

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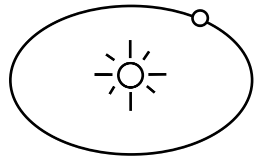
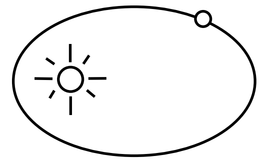


D.

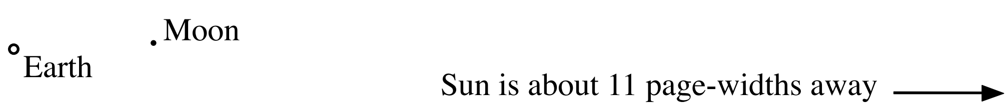


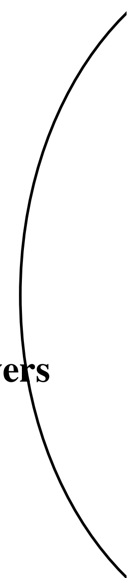
**Which drawing do you think most accurately shows the correct sizes and distances between Earth, the sun and the moon?**

A.


B.


C.



**Why is it hotter in Utah in June than it is in December? Circle all the answers you think are correct.**

A. The sun itself gives off more heat in June than it does in December.

B. Utah is closer to the sun in June than it is in December.

C. Earth is closer to the sun in June than it is in December.

D. There are more hours of daylight in Utah in June than in December.

E. Utah is facing more toward the sun in June and away from the sun in December.

F. The sun is higher in the sky in June which makes the sunlight more concentrated.

G. The moon blocks the sun more in December.

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| **Standard 02:**<br>Students will understand how Earth's tilt on its axis changes the length of daylight and creates the season.<br>**Objective 1:**<br>Describe the relationship between the tilt of Earth's axis and its yearly orbit around the sun. |

**<u>Activity 2:</u> Tracking the Sun -- Here it Comes Again**

**<u>Intended Learning Outcomes:</u>**

1-Use science process and thinking skills
2-Manifest scientific attitudes and interests
3-Understand science concepts and principles
4-Communicate effectively using science language and reasoning
5-Demonstrate awareness of social and historical aspects of science
6-Understand the nature of science

**<u>Teacher Background:</u>**

Most students think the sun rises due east, passes directly overhead, and sets due west. It is a strongly held misconception that the sun is overhead at noon, regardless of the time of year. Some students also believe that there are twelve hours of daylight every day. In actuality the sun rises and sets at different points along the horizon depending on the time of year. The sun is never directly overhead north of the tropic of Cancer or south of the Tropic of Capricorn. And, in fact, it is only directly overhead for two days at locations between the Tropic of Cancer and Tropic of Capricorn.

The zenith or high point of the sun is defined as local noon, but it is usually not exactly at 12 noon. How far a location is from the central meridian of the time zone (105 degrees west in the Mountain Time Zone) and daylight savings time both affect actual local noon.

**<u>Materials:</u>**

• plastic dome hemisphere, ideally one per four student team, available from Learning Technologies, 40 Cameron Avenue, Somerville, MA 02144, 800-537-8703 (sold in sets of 10, $19.00 per set)
Or
• clear round bowl or dome sectioned into quarters
• erasable overhead transparency markers or wax pencils for each team
• card stock with an outline of the dome and a large X dividing the dome into four equal sections, one per team.
• compass
• tape, chalk

**Invitation to Learn:**

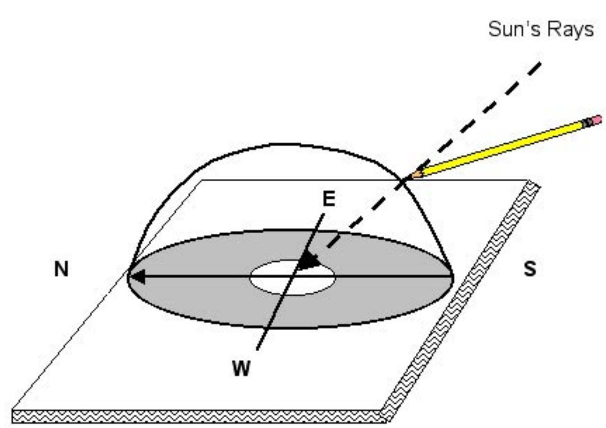
Hold up a clear plastic hemisphere and show the inside of the dome. Explain that the dome represents the sky. Tell them that where the ribs meet the base, this represents the directions north, south, east, and west. Label these direction points on the dome. Give each team or pair of students a clear plastic hemisphere. Have the students label the directions. Challenge them to predict where the sunrise was that morning. Use a transparency pen or wax pencil to write an R on the spot. Have them predict where the sun will be at noon. Write an N to record their prediction. Finally have them predict the sunset. Write an S on the location. Have them connect these points with a curved line to show the sun's path. Ask them: How could you find out if they are correct?

**Instructional Procedures:**

In this activity students plot the movement of the sun across the sky. As they make their own records over a period of time, they learn first hand the actual movement of the sun for their location. Before class calculate as closely as you can the exact location of north. First use a compass to find magnetic north. To find true north you will have to adjust the magnetic north direction about 15 degrees to the left (in Utah locations) to compensate for the difference between magnetic north and true north.

1. Have students place their dome on a flat, horizontal surface in direct sunlight. The dome should be directly over the circle on the cardstock. Oriented it so that the X on the cardstock is facing directly north and south and east and west. The ridges on the dome should align with the cross marks on the circle. The dome should always be placed in exactly the same position. Draw a line around the cardstock with chalk so that it can be aligned.

2. Plot the sun's position on the top of the dome. Carefully move the tip of the marker close to the plastic hemisphere, but do not let the marker touch the sphere. Move the marker around the outside of the dome until the shadow cast by its tip falls directly on the cross point of the X mark on the cardstock. Mark a dot on the hemisphere at this location. Label the time. The dome represents the sky and the mark represents where the sun appears in the sky at that particular date and time. As Earth rotates, the sun's position in the sky changes throughout the day.



3. You will need to decide when and how often the students record the sun's position. In part it will depend on how long a period you have your students. A teacher in a traditional elementary classroom will want to record the sun's position throughout the day, perhaps every fifteen minutes. When you have students for shorter periods of time you may have them record the sun's position every ten minutes for an entire class period. At each measurement the students will mark a dot as described in Step 2 and label the time for the plotting.

4. Either at the end of the day or the following class period have students connect the dots with a line. Draw the line on the inside of the hemisphere. Label the date for this line. Discuss the results of the observations. Ask the following questions. In what direction did the sun rise? Where is the sun at noon? (You may have volunteers track the sun during the noon period or share the domes that were created in classes who were in session at noon.) In what direction will the sun set?

5. Have students make predictions for future observations. Have students predict where the sun will be in two weeks? In December? In March? In June? This is a good time for students to record their observations and predictions in their science journals. Have them leave space for future observations.

6. Students should have opportunities to track the sun throughout the school year. Before each observation have students predict where the sun's path will be. Have students repeat their observations two weeks to one month later and continue throughout the school year. After the initial observation you may want students to plot the points at half or one hour intervals rather than every ten minutes. Ideally, begin observations at the beginning of the school year. Try to make observations before, on, and after the autumn and spring equinoxes and the winter solstice. (You may need to plan around Christmas vacation). Year round schools have the opportunity to observe the summer solstice. Label each new tracking with times and dates. You may use different colored pens to record each path of the sun.

7. Occasionally, perhaps once a month, discuss findings with students. Discuss the following questions: How is the sun's position in the sky changing? Why is this happening? Why is the sun higher or lower in the sky? Is the sun ever directly overhead? Why or why not? Discuss Earth's rotation and revolution. Help them relate their observations to the tilt of the Earth's axis. Toward the end of the school year have students make a final comparison of the differences in the sun's position.

**Possible Extensions/Adaptations/Integration:**

1. Give students opportunities to check out the hemisphere and compass and plot the sun in the morning as it rises and in the evening as it sets.
2. Have students graph the results of their observations. Begin by measuring the distance from the top of the dome to the sun's location at a particular time of day for several months. Then graph these measurements.
3. Have students record their own observations of sunrises and sunsets. Or alternatively they may consult almanacs, newspapers, or Internet sites to record sunrises and sunsets.

**Assessment Suggestions:**

1. Students keep a journal record of the sun's movements for one month.
2. Students make posters, picture books, charts, etc. showing how the sun's position changes in the sky throughout the year.

**Additional Resources:**

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| **Standard 02:**<br>Students will understand how Earth's tilt on its axis changes the length of daylight and creates the season.<br>**Objective 2:**<br>Explain how the relationship between the tilt of Earth's axis and its yearly orbit around the sun produces the seasons. |

Activity 3: Earth's Journey Around the Sun

**Intended Learning Outcomes:**

1-Use science process and thinking skills
4-Communicate effectively using science language and reasoning
5-Demonstrate awareness of social and historical aspects of science

Teacher Background:

Earth orbits the sun. Earth is slightly tilted (23.5 degrees) and spins on its axis. The north end of the axis always points toward the north star as Earth circles the sun. Because it is tilted and travels around the sun, we have seasons. The time it takes to complete an orbit is 365 1/4 days. Seasonal changes give us a change in temperature and a change in the length of daylight.

We live in the Northern Hemisphere. It is summer when the North pole is tilted toward the sun. At this time, the sun is high overhead and we receive strong sun rays. The sun shines for many hours each day. Its strong rays have a lot of time to heat Earth. In the far North, the sun shines for 24 hours a day. This gradually changes. Days get shorter and cooler, and the sun appears low in the sky at noon as the North pole moves slowly away from the sun. Summer turns to fall, and then to winter.

In winter, the North pole is tilted away from the sun. We do not receive the strong rays and the sun is low in the sky. The sun shines for fewer hours each day. These weak rays do not have time to heat Earth. This explains the colder winters even though the sun is shining. Winter turns to spring and then back to summer as Earth completes one journey around the sun.

**Materials:**

- globe mounted on its axis
- small table lamp
- small nail with a large head
- tape
- flexible ruler
- a sign labeled “North”

**Invitation to Learn:**

Ask students to predict why we have four seasons. Have the class discuss the predictions and talk about why the predictions may or may not be accurate. Lead a class discussion on what may cause seasonal changes. Do not give any answers to the class, just enough information to start them thinking and wondering. For example:

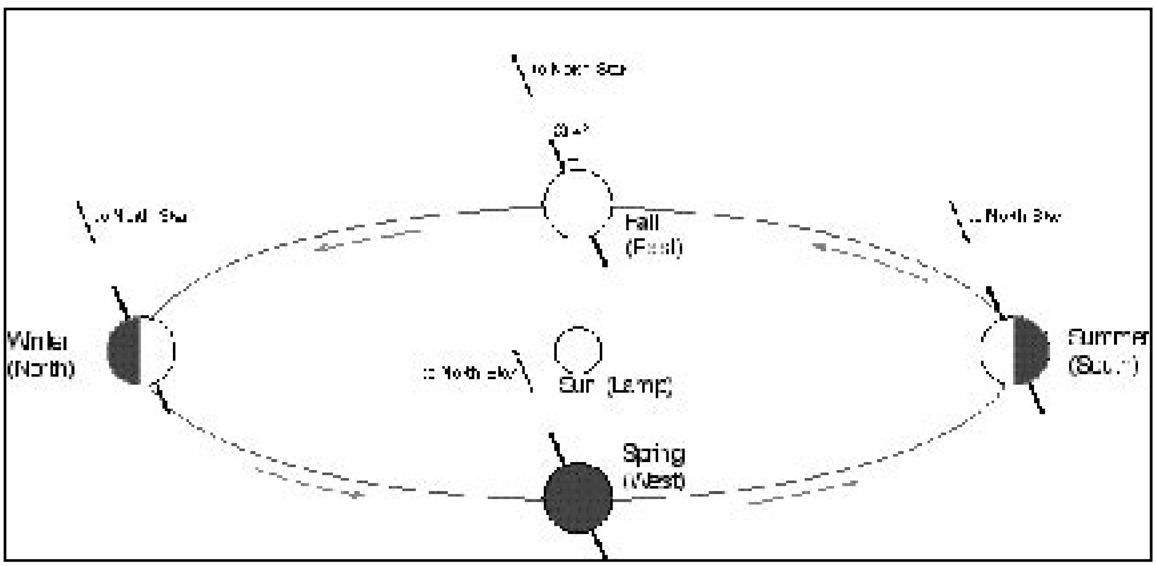
1. Think about how the sun feels on your face in the middle of June. Now think how it feels in December. Why do you think there is a difference?
2. If the sun is shining during the winter, why isn’t it as warm as when the sun is shining in the summer.
3. Does the length of daylight affect the temperature? When are the shortest days of the year? Is it colder then or when the sun shines for more hours? Why?
4. In the spring and in the fall, the length of daylight is about the same. However, it seems to be warmer in the fall. Can you predict why this is the case?

**Instructional Procedures:**

1. Have the students gather around the area where you will be working.
2. Place the lamp (shade removed) on the floor and turn it on. The lamp represents the sun.
3. Put the “North” sign down in the correct direction.
4. Find where we live on a tilted globe.
5. Place the globe on the ground on the south side of the sun. The globe should be tilted toward North. This is the summer position for the Northern Hemisphere. Ask the students what they notice about the sun’s rays.
6. Rotate the globe counter clockwise. One rotation represents one day or 24 hours. When light is shining on our location, it is day. When it is dark, it is night.
7. Repeat your observations for each of the other seasons. Move the globe counterclock- wise from summer (South) to fall (East) to winter (North) and spring (West). Make sure that the globe is always tilted toward north. Have students pay attention to the amount of sunshine we get during each season. Also, have them observe if the sunlight hits the Earth’s Northern Hemisphere at a large or small angle.
8. Remind students that when Earth makes one revolution (summer, fall, winter, and spring) one year has passed. It takes one year or 365 1/4 days for Earth to make one complete revolution around the sun.
9. Next, tape a small nail, head down, on top of the location where we live.
10. Have students predict what the nail’s shadow will look like in the summer position. Discuss predictions as a class. Next, have students record their predictions in their notebooks for what the nail’s shadow will look like for the other seasons.
11. Place the globe in the summer position (south of the sun).
12. Measure the length of the shadow produced by the nail. How does the shadow look? Were their predictions correct?
13. Move the globe to the other seasons, measuring the nail’s shadow for each season and discuss

the students predictions.

14. As a class, discuss the following questions: During which season is the nail's shadow shortest? During which season is it the longest? A short shadow indicates direct sunlight. A long shadow indicates weaker sunlight coming at an angle. During which season do you get the most daylight? During which season do you get about the same amount of daylight and darkness? In general, the stronger the sunlight during the day, the warmer the day.
15. Put the globe in the summer position one more time, this time have the students pay attention to the Southern Hemisphere. Ask students what season the Southern Hemisphere is having while we are having summer. Do the same demonstration for each of our seasons. Have students predict what season the Southern Hemisphere is  experiencing. Point out that seasons in the Southern Hemisphere are reversed from the Northern Hemisphere. Have students explain why this is the case.
16. Lead another class discussion with the same questions asked at the beginning of the activity. Students should realize that the angle of the sun's rays is a factor determining the seasons. They should also realize that when days are longer, the sun has a longer time to heat Earth.




Side view of Earth's orbit

**Possible Extensions/Adaptations/Integration:**

1. Remind students that seasons are reversed in the Southern Hemisphere. Have them write how their lives would be different if midsummer came in January, and midwinter came in July. Students might mention the change in how holidays are celebrated, when school is in session, or when vacations are taken.
2. Have students work in small groups to form explanations for why the hottest day of the year is usually not the longest day. Possible answer: The hottest day usually occurs in mid to late summer when Earth's surface has had a chance to retain enough solar energy to produce high temperatures.

**Assessment Suggestions:**

1. Have students write a paragraph explaining why the tilt of Earth's axis and its yearly orbit around the sun produces the seasons.
2. In their science journals, have students explain how the tilt of Earth affects our lives.
3. Have students draw a diagram depicting the four seasons and the relationship of Earth's tilt and the sun.

**Additional Resources:**

Gould, Alan, Carolyn Willard and Stephen Pompea. *The Real Reasons for Seasons Sun- Earth Connections*. GEMS Lawrence Hall of Science, University of Berkeley, CA, 2002.